SPECTROSCOPIC MEASUREMENTS OF THE PLASMA FROM A

PLASMA GUN I

NOBUKI KAWASHIMA, KENJI INOUE, MASATOSHI TANAKA

AND

SIGERU MORI

Japan Atomic Energy Research Institute

Ibaraki, Japan

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ABSTRACT

Line broadenings of He I 4471 and He II 4686 in the plasma generated in a Marshall type coaxial plasma gun are measured by a 340 cm Ebert type spectrometer. According to the Doppler shift measurement, a plasma is accelerated for about 5μ sec after the initiation of the gun discharge, and it leaves the plasma gun, while an unaccelerated plasma remains in the plasma gun after then during the discharge. Most of the line broadening in He II 4686 is due to Doppler broadening, and the Stark broadening is negligible. The accelerated plasma from the gun gradually loses the perpendicular component of the velocity to the axis of the plasma gun as it travels.

INTRODUCTION

The spectroscopic measurement is quite important in surveying the behavior of a plasma and the spatial variations of the plasma can be investigated by means of various informations obtained

from the spectroscopic measurement.

Here, the line broadening and the line shift of the spectral lines from a He plasma are investigated by means of 340 cm Ebert type spectrometer.

EXPERIMENTAL APPARATUS

The experimental layout is shown in Fig. 1. About 500μ sec after the injection of He gas through a fast-acting gas valve, a plasma is created by a condenser discharge. The capacitance of the condenser bank is 12μ F, and the ringing frequency of the discharge is 160kc/sec. The velocity of the accelerated plasma is about 5×10^6 cm/sec, and its density is ranging from 10^{14} to 10^{15} /cc.

The linear dispersion of the spectrometer is 2.5 Å/mm. The line profile is scanned by a photomultiplier, and the instrumental width at half maximum in this experiment is 0.11 Å.

RESULT OF THE EXPERIMENT

(a) Spectral Line Profile of the Accelerated Plasma

According to the radiation and double probe measurements, the time duration of the plasma from the plasma gun is about 10 sec, and its velocity is about 5×10^6 cm/sec. The spectra were taken in the direction perpendicular to the axis of the plasma gun, that is, perpendicular to the direction of the plasma stream. The line profiles of the He II 4686 line at 50 cm and 100 cm from the gun are shown in Fig. 2 and 3, respectively. As the density of the plasma stream is less than 10^{15} /cc, this broadening is mostly due to the Doppler broadening, and the Stark broadening is negligible. As the observation is perpendicular to the direction of the plasma

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stream, no Doppler shift was measured.

On the other hand, the direction of the ions on the plasma stream is not necessarily parallel to the axis of the plasma gun, and the ions have some velocity distribution in the component perpendicular to the axis of the gun. Therefore, the broadening in this measurement contains the broadening due to this ordered motion in the plasma as well as the temperature broadening.

As the plasma stream flows through a 6" glass tube, the ions with the velocity not parallel to the axis of the gun are gradually lost to the glass wall as they travel. This effect can be seen in Fig. 3, where the broadening is narrower than that in Fig. 2.

The accurate estimate of the ion temperature of the plasma is difficult due to this ordered motion, but as the ion-ion collision is rather frequent, the ion temperature may be obtained from this Doppler broadening.

(b) Spectroscopic measurement of the plasma in the plasma gun is an interesting problem in relation to the mechanism of the acceleration of the plasma in the plasma gun. Here, the time variations of He II 4686 and He I 4471 were measured. The observation was in the direction parallel to the axis of the gun. Fig. 4 shows the oscilloscope traces of the time variation of the He I 4471 and He II 4686. He I 4471 appears first, and then He II 4686 follows. This means that He I 4471 is radiated at the stage of ionization, Fig. 5 shows the time variation of the spectral intensities at various wave lengths around He II 4686. It can be seen in this figure that the line profile of the He II 4686 line varies with time, which is shown in Fig. 6. At 5μ sec after the discharge, the profile is broader than that at 25μ sec, and is Doppler

-shifted. The time variation of the Doppler shift of the He II 4686 line is shown in Fig. 7. Up to about 5μ sec after the discharge, the Doppler shift can be observed, but later it disappears. This can be explained as follows.

The discharge current with the period of 6μ sec flows in the plasma gun, and continues for about several periods. However, only the first one cycle of the discharge current contributes to the acceleration of the plasma, and the plasma produced by the discharge after that does not come out of the plasma gun. This has been verified by the magnetic probe measurement and the optical measurement. (Fig. 8) Therefore, the Doppler shift observed up to 5μ sec after the discharge is due to the accelerated plasma in the plasma gun. The velocity obtained from this Doppler shift well agrees with the one obtained by the time-of-flight measurement. The accelerated plasma is thought to be teared up to pieces at the muzzle of the gun by some unknown instabilities and a part of it comes out of the gun. So that the main portion of the optical radiation after then is due to the plasma remaining in the gun, and no Doppler shift can be observed. This is also verified by the time resolved photographs taken by use of a Kerr cell shutter. In Fig. 6, the broadening of the He II 4686 varies with time as well as the Doppler shift. The time variation of the line broadening is shown in Fig. 9. In order to investigate the effect of the Stark broadening, the line profile of the He I 4471 was taken, The time variation of the spectral intensities at various wave lengths around He I 4471. In contrast to the He II 4686, the Doppler shift can not be observed and the time variation of the broadening is not so large. (Fig. 11) The

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broadening itself is far less than that of the He II 4686, which means that the effect of the Stark broadening on the profile of the He II 4686 is negligible. The Doppler broadening versus the voltage of the plasma gun is shown in Fig. 12.

DISCUSSION

It can be said as to the behavior of the plasma, or especially the ions, in the plasma gun that;

- (a) The acceleration of the plasma is performed for about 5μ sec after the initiation of discharge, and the accelerated plasma comes out of the gun. In the gun, a low temperature plasma remains in the gun after then,
- (b) the Stark broadening is negligible, and the ion temperature in the gun is about 50 ev.
- (c) the plasma which comes out of the gun gradually loses the velocity component perpendicular to the axis of the plasma gun.

As many problems remain in the spectroscopic measurement of the plasma in the plasma gun further investigation is now being performed as not only to the line profile but also to the electron temperature measurement and the effect of the impurities.

Reference

- (1) H. R. Griem

Stark broadening of Hydrogen and Hydrogenic Neutral and Ionized Helium Lines in a Plasma.

N R L 5805 (1962)

- Fig. 1 Experimental Layout
- Fig. 2 Line Profile of He II 4686 at 50 cm from the Gun.
- Fig. 3 Line Profile of He II 4686 at 100 cm from the Gun.
- Fig. 4 Oscilloscope Traces of the Spectral Lines
Upper Trace : He II 4686
Lower Trace : He I 4471
Sweep 5μ sec/div
- Fig. 5 Time Variation of the Spectral Intensities at various Wave Lengths around He II 4686
- Fig. 6 Line Profiles of He II 4686 at 5μ sec and 25μ sec after the Initiation of the Discharge
- Fig. 7 Time variation of the Doppler Shift of He II 4686
- Fig. 9 Magnetic Probe Measurement in the Plasma Gun.
- Fig. 10 Time Variation of the Spectral Intensities at various Wave Lengths around He I 4471
- Fig. 11 Time Variation of the Profile of He I 4471
- Fig. 12 Doppler Broadening of He II 4686 versus the Voltage of the Plasma Gun.

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(a)

(b)

Fig.4

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Fig. 5

Fig. 6

Fig. 8

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Fig. 10

Fig. 11

Fig. 12